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Research on the 3D Solid Modeling of High Efficient Gear Tooth Based On Pro/E

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Abstract

Utilize the coordinate transformation method to establish the surface equation for gear tooth. Techniques such as feature modeling, parametric driving, two-dimensional and three-dimensional full dynamical correlation are also used to process the tooth surface and add features according to the relationship between individual features and creating order. A number of rotation and duplication is also utilized to obtain all the cogging, finally completing the detail design for each feature. This method has avoided the shortcomings of traditional three-dimensional dynamic assembly and excessive motion simulation computing, greatly improved the operational efficiency, reduced the size of storage file and decreased requirements for computer hardware.

Keywords: Three-dimensional modeling;Dimension-driving;Boolean operation;Coordinate transformation

1. Introduction

Use Pro / E software to create three-dimensional model for each component of reducer. This model is based on some advanced techniques such as feature modeling, parameter-driving, single database, 2D and 3D full dynamical correlation, so it is a kind of complete model which can express and process three-dimensional objects. Feature is the geometric entity with engineering meaning, that is, a comprehensive description after reasonable abstraction for information set such as the shape structure, process, assembly, function and the correlation of the design object. In addition, it is also the most basic design and operation unit of three-dimensional modeling using Pro/E software[1]. Model is the combination of various features,

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which is achieved by 2D cross-section sketch as well as the extruding, revolving, scanning, chamfering, Boolean operations and so on.

Utilize simple features to form the model as much as possible, for Pro/E software is driven by the size, therefore, if the features are simpler, the size will be smaller[2]. The future modification, re-design and edit will become easier, which can enable the design intent to be more flexible. Utilize the linkage of graphical features as much as possible, that is, geometric constraints have priority to size constraints in order to ensure the correct model parts as well as avoid ambiguity of features. To improve the efficiency of the system's modeling, the component should be analyzed before the design and examine it from the overall look to form the general idea about it, determine the composition, creating order and improvement of its features[3].

2. Establish the surface equation of gear

Establish the coordinate system and assume that $\sigma_0(o;x_0,y_0,z_0)$ is fixed in the pinion cutter, $\sigma_1(o;x_1,y_1,z_1)$ is fixed in the pinion cutter which is to be processed. $\sigma_0^{'}(o;x_0^{'},y_0^{'},z_0^{'})$ and $\sigma_1^{'}(o;x_1^{'},y_1^{'},z_1^{'})$ is respectively the fixed coordinate of σ_0 and σ_1 at the initial time[4].

Apply the tooth surface equation of pinion cutter to the coordinate system σ_1 and the transformation relation of the coordinate systems is as shown in Fig.1.The coordinate transformation process is $\sigma_0 \to \sigma_0' \to \sigma_1' \to \sigma_1$.

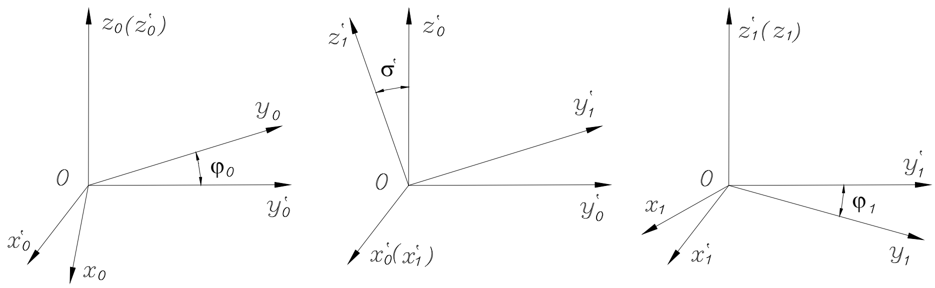

Fig. 1. transformation relation of the coordinate systems

The coordinate transformation matrix of $\to \sigma_0'$ is $M_{0'0}$.

The coordinate transformation matrix of $\sigma_0' \to \sigma_1'$ is $M_{1'0'}$:

$$M_{0'0} = \begin{bmatrix} \cos\varphi_0 & -\sin\varphi_0 & 0 \\ \sin\varphi_0 & \cos\varphi_0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad M_{1'0'} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -\cos\sigma' & \sin\sigma' \\ 0 & \sin\sigma' & \cos\sigma' \end{bmatrix}$$

The coordinate transformation matrix of $\sigma_1' \to \sigma_1$ is:

$$M_{11'} = \begin{bmatrix} \cos\varphi_1 & -\sin\varphi_1 & 0 \\ \sin\varphi_1 & \cos\varphi_1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Therefore, the coordinate transformation matrix of $\sigma_0 \rightarrow \sigma_1$ is shown as follows:

$$M_{10} = M_{11'} \cdot M_{1'0'} \cdot M_{0'0} = \begin{bmatrix} \cos\varphi_0\cos\varphi_1 + \cos\sigma'\sin\varphi_0\cos\varphi_1 & -\sin\varphi_0\cos\varphi_1 + \cos\sigma'\cos\varphi_0\sin\varphi_1 & -\sin\sigma'\sin\varphi_1 \\ \cos\varphi_0\sin\varphi_1 - \cos\sigma'\sin\varphi_0\cos\varphi_1 & -\sin\varphi_0\sin\varphi_1 - \cos\sigma'\cos\varphi_0\cos\varphi_1 & \sin\sigma'\cos\varphi_1 \\ \sin\sigma'\sin\varphi_0 & \sin\sigma'\cos\varphi_0 & \cos\sigma' \end{bmatrix} \quad (1)$$

Finally, the equation of tooth profile Σ_1 of beveloid external gear to be processed in frame σ_1 is:

$$[x_1 \quad y_1 \quad z_1]^T = M_{10}[x_0 \quad y_0 \quad z_0]^T$$

When deducing the tooth profile surface equation of internal gear, set the axis y_0 of pinion cutter to be the coordinate of tooth thickness symmetry, and the obtained axis y_2 of tooth profile surface equation of internal gear to be the coordinate of inter-tooth symmetry. Using the same methods and procedures, the equation of tooth profile surface Σ_2 of the beveloid internal gear in the frame σ_2 can be obtained:

Make $\beta_0 = \delta_0 - \theta_0 - \varphi_0$, and

$$\left.\begin{aligned} x_2 &= r_{0b}\cos\varphi_2[\sin\beta_0 - \delta_0\cos\beta_0] + r_{0b}\cos\sigma_2'\sin\varphi_2(\cos\beta_0 + \delta_0\sin\beta_0) \\ &\quad + \frac{r_{0b}\sin\varphi_2(i_{02} - \cos\sigma_2')}{\cos\beta_0} \\ y_2 &= r_{0b}\sin\varphi_2(-\sin\beta_0 + \delta_0\cos\beta_0) + r_{0b}\cos\sigma_2'\cos\varphi_2(\cos\beta_0 + \delta_0\sin\beta_0) \\ &\quad + \frac{r_{0b}\cos\varphi_2(i_{02} - \cos\sigma_2')}{\cos\beta_0} \\ z_2 &= -r_{0b}\sin\sigma_2'[\cos\beta_0 + \delta_0\sin\beta_0] + \frac{r_{0b}(i_{02} - \cos\sigma_2')}{\tan\sigma_2'\cos\beta_0} \end{aligned}\right\} \quad (2)$$

φ_2 —rotor angle of the beveloid external gear ($^\circ$); i_{02} —velocity ratio of pinion cutter and beveloid external gear; σ_2' —bevel angle ($^\circ$) of slotting beveloid external gear.

3. Method of high efficient modeling of gear

Although the three-dimensional solid modeling of traditional gear has high precision, its computing is excessively complex for three-dimensional dynamic assembly and motion simulation, which requires advanced computer hardware[5]. Therefore, a relatively simple and quick way for rapid modeling is in dire need. This paper proposes the 3D solid modeling of high efficient gear tooth based on Pro/E, shown as follows.

The processing method of beveloid gear is to conduct oblique slotting using the standard pinion cutter. By virtue of the fact that there is a oblique angle between pinion cutter and the axis of gear blank, a simple method for three-dimensional solid modeling of beveloid gear is proposed. A case in point is the modeling process of shells of beveloid internal gear.

(1)Regard the RIGHT datum plane as the cross-section sketch and utilize the tool of “spin” to draw a rough shell, as shown in Fig.2. Then the key point lies in the process of gear tooth cutting on the blank.

Then establish the datum plane DTM1, make the angle between DTM1 and the datum plane TOP-the end face of the shell is equal to the oblique angle.

Fig. 2.the rough shell generated by rotation

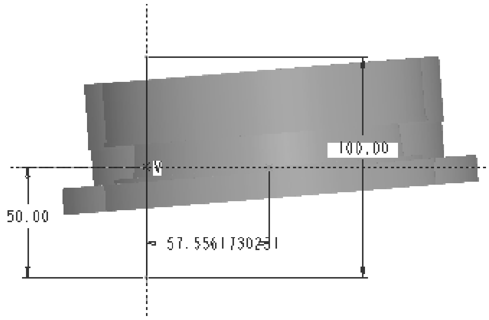

Fig. 3. Scanning of variable section

(2) Various ways can be used to draw involute profile and this paper selects the "Variable Section Scanning" as the tool, for this method can draw standard involute easily and the obtained file is small, so it is very appropriate. Select the "Variable Section Scanning", and the sketched curve is the default scanning path of the system. Then start the sketch mode after selecting appropriate orientation, draw a straight line as the scanning curve of Variable Section Scanning, and mark the distance between the straight line and the sketch center, as shown in Fig.3.

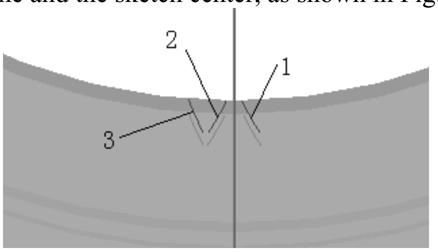

Fig. 4. mirroring and duplication

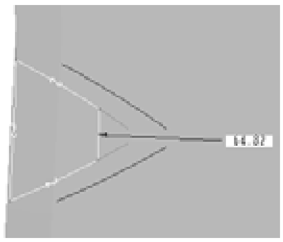

Fig. 5. sketch of mixing section

(3) Use the tool of "intersection" and take the intersecting line between the two end faces of the shell's top gear and the involute surface. Fig. 4 is the front view of components, in which curve 1 indicates that line of intersection. Then the RIGT datum plane (projecting as a straight line in the figure) is regarded as the mirror image 2 to get the curve 2. The rotation and duplication in feature operation is then utilized to duplicate the curve 1 with the input rotor angle of $2\pi / n$ (n refers to the number of teeth) to get the curve 3, as shown in Fig. 4.

(4) Fig.4 indicates that cogging lies in the part between curve 2 and curve 3, so the following operation is to cut this part. Since this is irregular stretching and removal, this paper uses a "mixing" approach. First sketch the cross-section using the end face of the gear, as shown in Fig.5. The surface sketch is divided into four sections, namely, curve 2 and curve 3 in Fig.4, the addendum circle and the root circle, the first three parts are to directly select the existing curve, while the root circle is sketched with the marked size in the figure as its radius. Finally, cut off the excess part to get the closed sectional view.

Utilize the tool of "cut" in "mixing" and regard the two plane figures which are drawn just now as the mixed section, then the cogging can be obtained after selecting the corresponding vertex. Make filleting on the four edges of the tooth crest and tooth root; it is not necessary for the filleting to be oversized, for example, 0.2mm. The single cogging which has been completed is as shown in Fig. 6.

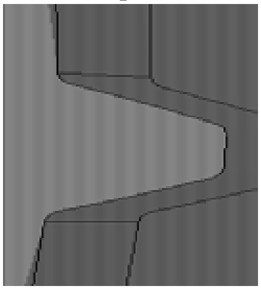

Fig. 6. cogging after filleting

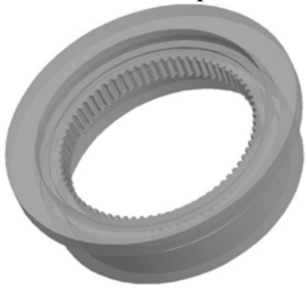

Fig. 7. behaviod internal gear generated by duplication

(5)Finally, the array tool can be utilized to generate the complete gear tooth, which is simple and convenient, however, due to its large consumption of memory space, more advanced computer hardware is required, so it is not appropriate to apply this method in such complex models such as behaviod gear. To solve this problem, in this paper, a number of rotation and duplication is utilized to obtain all the cogging, ten tooth at a time. Although this method is somewhat tedious in operation, in fact it has greatly improved operational efficiency, decreased the size of store file and reduced requirements for computer hardware. This operation generates the gear ring for behaviod inner gear, as shown in Fig.7.

4. Conclusions

1. Complete the three-dimensional solid modeling of components of reducer, summarize the modeling techniques, and introduce the modeling process of components taking the shell of behaviod inner gear as an example.

2. Component modeling is a process from coarse to fine. First create the rough model for components, and then add features according to the relationship between the various features and the creating order, finally complete the details. For each individual feature, its relationship with others should be cleared and the internal link also needs attention.

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